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How important is an ensemble of statistical downscaling methods in urban climate change impact studies?

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Abstract

Climate model projections point to increasing extreme summer precipitation amounts and, hence, summer floods will occur more frequently. As such, urban climate change impact studies find ground in our society. These studies face, however, various uncertainty sources and, therefore, require a multi-ensemble approach. Most urban impact studies consider an ensemble of climate model runs, which in turn, account for different representative concentration pathways. An ensemble of statistical downscaling methods or the impact of using one particular statistical downscaling method is often neglected. This study focuses on the importance of the ensemble of statistical downscaling methods in urban climate change impact studies. More specifically, the influence of the ensemble size (one method versus multiple methods) and composition (which method or methods) is investigated using fast-simulating conceptual urban models. Application of a (complete) multi-ensemble approach demonstrates the importance of also accounting for the statistical downscaling uncertainty, and illustrates the potential and benefits of using conceptual impact models.

Different statistical downscaling methods exist based on various concepts, such as transfer functions, rainfall generators and weather typing methods or model output statistical and perfect prognosis methods. To account for the uncertainty inherent to these methods, i.e. statistical downscaling uncertainty, an ensemble of different approaches should be considered. Although, this concept is well established in hydrological impact studies, it is foremost not applied in urban impact studies. This might be due to computational limitations of the impact model, impeding simulating many input series, or the limited availability of statistical downscaling methods producing projected time series with the necessary sub-daily time step. This research investigates different downscaling methods, including a quantile perturbation method (Ntegeka et al., 2014), an event based perturbation method (Sørup et al., 2017), a weather typing based method (Willems and Vrac, 2011), an event based rainfall generator (Thorndahl et al., 2017) and a Newton Scott Rectangular Pulses based rainfall generator (Burton et al., 2008). The resulting projected time series are applied to impact models, followed by an inter-comparison of the obtained impact results to quantify the influence of each method. Moreover, using variance decomposition, the variance of the projected impact results is studied and information on the statistical downscaling uncertainty contribution is acquired. This information provides an answer to whether an ensemble of statistical downscaling methods is required or one method is sufficient. Furthermore, when applying one particular statistical downscaling method or designing an ensemble of methods, knowledge on method limitations and strengths is a prerequisite. For this purpose, the perfect predictor experiment - a validation outline set up on the occasion of the VALUE project (Maraun et al., 2015 and 2017) - is applied for the ensemble considered and extended to the urban drainage impact analysis.

Above analyses use the 100-year time series of precipitation intensities measured at Uccle (Belgium), 30 global climate model runs and 5 statistical downscaling methods. Considering ensembles of both climate model runs and statistical downscaling methods leads to a vast amount of projected time series that must be simulated in urban impact models. To ensure that these simulations can be performed in a limited time span, this study proposes the urban hydraulic conceptual modelling approach developed by Wolfs and Willems (2017). This methodology results in simplified models that can simulate long-term time series in a few seconds. Such fast simulating models enable both simulating ensembles of input series and sensitivity analyses of the impact model itself. Different parameterisations of the conceptual impact model are considered to represent typical configurations of Belgian urban hydraulic infrastructure, such as rain water tanks, infiltration basins and sewers.

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